RESEARCH NOTE 81-5

LEVEL II

THE FEASIBILITY OF EMBEDDING SKILL QUALIFICATION TESTING SOFTWARE IN ONE OR MORE OF SIX WEAPONS SYSTEMS

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Previous research has validated the concept of Embedded Training (ET) by installing a powerful, machine transportable Computer Assisted Instructional (CAI) authoring language and software system known as PLANIT (Programming LANguage for Interactive Teaching) on the Field Artillery's Tactical Fire Direction Computer System (TACFIRE). Subsequent research demonstrated that the same hardware and software could be used for the administration of an embedded Skill Qualification Test (SQT). The purpose of this study was to determine the feasibility of transferring ET and embedded SQT technology to existing Army Air Defense Weapons Systems. next page

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Six Air Defense Weapons Systems were examined: TSQ-73, HAWK, FAAR, PATRIOT, ROLAND, and DIVAD. In general, the results indicated that it would be impractical to attempt to run PLANIT on any of the air defense weapons computers, but that PLANIT could be run on an adjunct computer and be made to satisfy the training/testing needs by using a fabricated terminal very similar to the authentic one.

The development of such a prototype for an "off-line" embedded SQT capability could be produced for one of the selected Air Defense systems in a short time and for a relatively low cost. If successful, the resulting technology would have application not only to existing systems, but to new Air Defense systems to come into the inventory in the 1980's.

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THE FEASIBILITY OF EMBEDDING SKILL QUALIFICATION TESTING SOFTWARE IN ONE OR MORE OF SIX WEAPONS SYSTEMS

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THE FEASIBILITY OF EMBEDDING
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I. INTRODUCTION

Modern weapons systems are demanding more highly skilled operators than ever before because at the heart of an increasing number of these systems is an electronic digital computer. The training, maintenance and verification of required skill levels for operators is a major endeavor, particularly in light of the fact that skilled operators must be on call virtually anyplace in the world to perform complex tasks at a moment's notice which they now have little opportunity to practice.

Little, if any, formal preparation may be assumed for those who are to become operators. Many soldiers will come into contact with a digital computer for the first time in their lives when the training begins. The problem is further complicated by a guaranteed periodic turnover giving rise to the continual need to resupply the operator pool.

Not only are the operators required to make these computerized systems function as intended, but they must also be prepared to fix the equipment when it malfunctions. There will be little opportunity to call out the manufacturer's repairmen on the battlefield.

As if the enormous training problems were not enough, the training conditions add yet more obstacles. Equipment is generally expensive and scarce. Fielded systems are usually deployed as they become available. Prior to fielding, what few pieces of equipment that are available are often committed to hardware and/or software development. Few are available solely for training and testing.

The US Army Air Defense School (USAADS) at Ft. Bliss conducts training and testing for operators of many of these systems. It is necessary in most instances for potential operators to go to Ft. Bliss to receive the training. The travel and lost time is of course expensive, but it would also be expensive, probably prohibitively so, to transport the present training instructors and materiel to the field to conduct the sessions there. And, of course, these conditions do not pertain only to new operators. Skill level maintenance, especially during peacetime, is an equally critical problem. These complex learned skills tend to fade quickly with lack of use. As it now stands, many of the soldiers must return periodically to Ft. Bliss for additional training in order to maintain a desired level of military preparedness.

USAADS is aware of these training obstacles as much as anyone, and is constantly searching for improved methods for carrying out its training mission. Having participated in a demonstration of an automated, embedded Skills Qualification Testing demonstration on the TACFIRE system at Ft. Sill (to be discussed below), USAADS initiated a study of six weapons systems at Ft. Bliss for which it has training responsibility, to determine whether a similar capability might be advantageous for these systems. (The six systems are TSQ/73, FAAR, DIVAD, ROLAND, HAWK and PATRIOT). Accordingly, USAADS asked the US Army Research Institute (ARI), whose field office is located at Ft. Bliss, to conduct such a study. The subject of this document is the discussion of the feasibility of adding an automated, embedded training and testing component to any or all of the above six systems.

II. BACKGROUND

The software system which is under consideration for embedding in the above weapons systems is called PLANIT (Programming Language for Interactive Teaching). PLANIT is already known to the Army. ARI began their work with PLANIT in 1973 in a demonstration of embedded training on the DEVTOS system at Ft. Hood. In preparation for the formal demonstration, scheduled as MASSTER Test 122, ARI conducted an extensive search of all extant software systems that could be embedded and used to deliver training. PLANIT alone satisfied all of the requirements (Hoyt, Butler and Bennik, 1974).

At that time, however, PLANIT was a new and error-prone system. But it was also a comprehensive training and testing system, and it was transportable. So ARI continued to sponsor applications of PLANIT in a variety of hardware environments, both military and commercial.

In regard to commercial computing environments, ARI's interest was twofold: to validate whether and to what extent the PLANIT software was in fact transportable, and to provide an easily accessible authoring facility so that training and testing scripts could be prepared and checked prior to their use on the tactical systems for which they were intended.

In the first case, ARI rightly wanted assurance that PLANIT's transportability claim was valid, and that implementations were not going to fail after the development money was spent. In this regard, PLANIT implementations were tried on computers not even envisioned when the software was originally designed, including military computers, minicomputers and microcomputers. Computers included the CDC 3300 (DEVTOS and ARI headquarters), CDC 6400 (Ft. Leavenworth), Litton L-3050 (TACFIRE), Univac 1108 (Edgewood Arsenal), Digital Equipment PDP 11/45 (a minicomputer), Texas Instrument 990/10 (a large microcomputer), and Cromemco Z-80 (a small microcomputer). Each implementation represented a different dimension in difficulty, and the series of successes collectively confirmed PLANIT's transportability.

In addition to validating transportability, ARI's commercial implementations of PLANIT have allowed the development of training software for military computers while incurring very little demand for use of the tactical equipment to do it. Actually, the tactical equipment was only needed for final checkout, to confirm that the training and/or testing scripts functioned properly. This has saved countless contact hours with the busy and expensive military computers, particularly with TACFIRE.

The TACFIRE experience has been highly successful. By now, PLANIT is a refined, highly dependable system, and the scripts which PLANIT executes on TACFIRE affords a realism which a skilled TACFIRE operator can easily mistake for the actual tactical software. Thus, the training and testing environments contain all the fidelity that one could wish for a Hands On Component, assuring a high degree of validity for the session.

TACFIRE was the most ambitious military implementation of PLANIT to date. This was an ARI-sponsored joint effort between two contractors, Litton Data Systems (the hardware manufacturer) and the developer of PLANIT (See Frye, 1975). PLANIT loads from tape cartridges onto TACFIRE (i.e. the L-3050 computer, also designated the AN/GYK-12 computer). In this case the tactical and training software cannot run concurrently. The space constraints in TACFIRE provides virtually no extra room when either system is running, but it is adequate.

Numerous training and Skills Qualification Testing sessions have been conducted in an automated mode using the TACFIRE hardware. It is not even necessary to have a proctor present during these sessions. Foolproof data collection methods insure valid assessment. The script contains, in addition to the SQT, a debriefing session for the soldier and a complete report of his or her performance, all fully automated. There are no required hardware modifications, and the entire training or SQT script can fit onto one tape cartridge, which can be sent to any TACFIRE site in the field.

It was during one of the demonstrations on TACFIRE of automated SQT presentation that USAADS officers revealed their interest in exploring similar kinds of capabilities for weapons systems at Ft. Bliss, noting that the L-3050 computer used in TACFIRE is virtually the same as the one used in the TSQ-73 Air Defense System. Thus, this preliminary feasibility report was commissioned through ARI to assess the potential for embedding an SQT facility into one or more of the six air defense weapons systems, named above, in a manner which would afford the advantages seen in the TACFIRE demonstration.

III. CONCEPT CLARIFICATIONS

There is a natural ambiguity in the use of some terms and concepts which can cause the same discussion to be interpreted differently by different readers. This section discusses what is meant here by some of the predictably confusing terms.

A. Skills Qualification Testing Vs. Training

There is little doubt among military readers about the meaning of SQT's, and particularly the Hands On Component (HOC) being discussed in this report. This is the assessment of the soldier's skill while actually operating the equipment. It is the feasibility of using PLANIT to facilitate the HOC SQT that occasions the present report.

However, it perhaps should be clarified that the PLANIT software being considered for SQT administration is no different than the PLANIT being used elsewhere for training. In fact, PLANIT is more than a training vehicle; it is also a total instructional management system where student performance is continually being assessed by individual responses, by topic and by completed course indicators. It is entirely possible to continue a student on an automated learning track for as long as one desires. The relevance of this capability to the present subject is that PLANIT contains full testing capabilities along with the training capabilities, and the PLANIT system is not divided or compartmentalized among the two. Thus, if PLANIT is implemented on one or more of the six proposed air defense systems, those systems will also acquire a complete, new training system as well. This added capability comes at no extra cost since it is the total PLANIT system that is transportable, not just the building blocks. To divide that system for the purpose of supressing the training capabilities would cost considerably more because it would entail surgery on a completed system.

The reason for this discussion is to assure the reader that the training component in the PLANIT system, referred to herein, is not an added cost item. To the contrary, it would cost extra to leave it out. However, this does not in any way diminish PLANIT's testing capabilities, since the "total system" concept behind PLANIT required these capabilities to be present as well.

B. Training Vs. Exercising

The Army already has "Trainers," developed at great expense, for many of its weapons systems. They permit the introduction of simulated "targets" along with varying countermeasures to enhance the perception of realism. The value of these simulators is not being questioned. They probably are a vital link in the total preparedness of operators whatever other training media are used. However, this report distinguishes between operating during a simulated raid and operating in a true training mode. We are calling the former, "exercise," not training.

The distinction being drawn is based on the fact that a weapons system operating in a simulated raid mode will teach a novice operator nothing more than if it was being operated in a combat situation. In fact, the teaching is not being done by the simulation at all, but by the experienced instructor who also attends the session and debriefs the trainee afterward. Remove the instructor and little or no learning will take place. The distinction is that there is no instructional strategy built into the software of the simulators. The strategy is all tactical, and the system operates in the simulation mode exactly as it does in the combat mode.

A training system, on the other hand, enforces desired response behaviors. If the trainee does not take a certain action at the appropriate time, the system stops, corrects that behavior through interaction, perhaps backs up, and goes past that critical point again. This can be repeated until the trainee does it right. Rather than to complete the exercise and then find out what errors were made, a training system will not allow the session to proceed in an error situation.

Suppose the system in view was a Link Trainer, and the curriculum was about landing approaches. Then a trainee in the exercise mode who flew under the proper approach would likely "crash," whereas in the training mode, the trainer would stop as soon as the trainee had veered from the approved approach path, "back up" the airplane, tell the trainee where he went wrong, and resume the landing.

There is a danger of oversimplification in regard to a training system because the strategy followed after missed responses depends entirely on the lesson script which was previously devised by its author. The author has the freedom to make the trainee suffer the consequences, advise the trainee and replay the sequence, stop the session, switch to a less demanding script, or whatever. This is the value of PLANIT. Any competent person who knows the task and the behaviors to be taught can use PLANIT to author training scripts with these described characteristics, and then PLANIT will faithfully administer the scripts to trainees exactly as they were prescribed.

The PLANIT kind of training vehicle is not meant to be a substitute for full-dress simulations. There will still be the need to exercise in the context of combat conditions but without the attentant risks. However, the PLANIT system will provide meaningful training on target equipment without the need for an instructor or proctor to be present.

Thus, this report will proceed to direct the discussion primarily toward embedded SQT's, but the reader should also be aware that making PLANIT available for SQT applications carries with it a new and complete repertoire of training capabilities.

C. Testing Vs. Supervised Exercising

This third point ties together the relevance of the previous two points in regard to embedded SQT's.

There are two common characteristics of testing which may also be desirable for SQT procedures, particularly involving the HOC of weapons system operator assessment. The two are: a) sampling behavior and b) establishing a pass/fail criterion.

It is not always reasonable to include in the test all of the operating procedures which form a part of the task. This would often make the test unmanageably long, and is probably unnecessary. Rather, several critical behaviors are "sampled" in the test, with the assumption that if the candidate performs well on the sample of expected skills, then the chances are good that the person is a competent operator.

Also, accepted testing procedure rarely demands perfect performance on the test, even if the test consists only of a sampling of important skills. Typically, a pass/fail criterion score is established prior to giving the test. These methods are not new for SQT's. Both are characteristically true.

However, the practice of using a simulated raid capability to administer the HOC of the SQT causes one to be perilously close to violating both principles despite the best of efforts to ensure them.

Regarding the first principle, that of sampling desired behaviors, this procedure is valid so long as the sample is truly representative of the various important skills, or at least is statistically random. Using a simulation facility, the testing will not be random, so the remaining question is whether the important skills are being sampled representatively. Probably not. It would be terribly inconvient to measure a sample of a soldier's performance over some arbitrary 30-second period of a simulated raid, and to do it repeatedly within the several different important contexts. The simulations just don't operate that way. The test usually turns out to be a simulated raid from beginning to end, rather than a sample of performance during a variety of raid conditions. If the entire raid constitutes the sample, then a valid SQT would need to include many such raids in order to satisfy the variety of conditions which might exist. Again, time becomes a problem. Thus, one must conclude that the typical HOC SQTs using simulated raid tapes do not really satisfy sampling assumptions insofar as one would use sampled performance to determine overall proficiency.

Adherence to the second principle also is a problem when raid simulation is used to assess performance in relation to some established criterion. Let's suppose the SQT pass/fail criterion is set at 80% such that the soldier must be correct four out of five times to pass. The problem which the simulated raid system introduces is that the test sequence is fixed in serial order and the events are not independent. Faulty performance at one point in the test can so alter the events that it would be virtually impossible to perform correctly on some following ones.

Again, this is due to the manner in which the simulation is designed to progress. During simulation, the system is supposed to perform no differently than during an actual raid.

This discussion is not intended to be critical of simulation facilities. Indeed, their role has already been acknowledged to be vital. However, that does not necessarily make them a good testing vehicle. Generally, for a test, one would want the performance items to be as independent as possible, and if the soldier performed badly on one item, the remainder of the test should proceed unchanged. To translate that into a desirable HOC SQT, faulty performance at any one point in the test should be recorded, but the remainder of the test should proceed just as though every response was correct. This might mean that a hostile target which was incorrectly overlooked would no longer pose a threat after that particular sampled performance was recorded. This, of course, is not the way simulators are designed. However, it is quite possible for PLANIT to administer that form of test, including both sampling and independence of events.

D. Embedding

Embedded training and/or SQT's could be understood as the literal inclusion of these capabilities into the tactical system. It is not being used in that strict a sense here.

Even the TACFIRE implementation of PLANIT is not embedded in the literal sense because the tactical system must be removed to make room for PLANIT. PLANIT is only embedded in the TACFIRE hardware, not in the full tactical system.

This report will show that PLANIT will not even embed in the present hardware of the above six named air defense weapons systems. Thus, the term "embed" is being used more generally to refer to training and HOC SQT capabilities which can exist in the same environment as the tactical equipment, and in a form that does not require traditional classroom or proctored sessions to benefit from the interaction.

IV. RELEVANCE OF PLANIT ON TACFIRE TO USAADS

Since the current inquiry regarding the possible usefulness of PLANIT at USAADS grew out of the TACFIRE experience, it is appropriate to look at the commonality of the two.

A. Both Are Tactical Fire Control Systems

In comparing TACFIRE to representative systems at USAADS, each is generally used for the purpose of assigning an assortment of weaponry to invading hostile targets. Each maintains current battle status information, including such things as available fire power, geographic and topographical information, identification of ground combat zones, air corridors, etc. Each is commonly networked in configurations analogous to divisions, battalions and fire units, although this may vary.

B. Commonality of Some Equipment

Both TACFIRE and one USAADS system (TSQ-73) use the same generic kind of computer (i.e. the Litton L-3050). It may have been this fact more than any other that first brought to the attention of USAADS personnel the possibility of using PLANIT.

C. ARI Research and Development Assistance

The Army Research Institute has played the predominant role in the development of PLANIT-administered training and SQT applications on TACFIRE. The fact that ARI maintains a Field Unit both at Ft. Sill and Ft. Bliss, coupled with ARI personnel's present involvement with USAADS' weapons systems, provides excellent opportunity for needed liaison to see that PLANIT is used productively at Ft. Bliss as well. Indeed, because of the history of their experiences, the ARI personnels' knowledge of PLANIT is second only to that of its developer.

D. Important Differences

Despite the many commonalities between the TACFIRE PLANIT at Ft. Sill and comparable needs for air defense systems at Ft. Bliss, there are some important differences between the two which will impact any attempt to use PLANIT at USAADS. Many of these differences can be pointed out by USAADS personnel more intelligently than by this author. However, some which are readily seen to impact the use of PLANIT are enumerated below:

1. The range of appropriate operator responses on TACFIRE is limited to a reasonably restricted set of switch actions and typed verbal responses (completions of message formats which are called to the screen). These actions typically follow a prescribed order, and operator options are limited to an easily manageable few. In contrast, USAADS commonly deals with weapons systems in which operators are interacting with radar-swept displays, using their own descretion (for the most part) to establish the order in which they will pursue their task.

2. TACFIRE is predominantly a message-handling system; assembling, sorting, editing, reviewing and transmitting messages from target observers to the gun batteries. Of course some of the message editing is performed automatically by the computer as it recalculates exact target information from observer-supplied data, but much of it is also performed by operators. Their role is reasonably easy to define and capture in PLANIT testing and training scripts. Much uncertainty remains about how PLANIT scripts can meaningfully capture the more flexible task of air defense system operators at USAADS. Even with PLANIT successfully installed on one or more USAADS' weapons systems, there will still be a significant amount of exploratory work to see how this new tool can most effectively be used.

3. Despite actual hardware similarity between computers in TACFIRE and TSQ-73, vital differences yet remain which may preclude using existing computer hardware to run PLANIT. Aside from

TSQ-73, computer availability is questionable. In FARR, for example, there is no computer available for other applications. The HAWK computer similarly is probably too special in purpose to be of use for PLANIT. But beyond that, none of the computers in any of the six weapons systems in view presently contains enough memory to run PLANIT, and the proposed expansions of TSQ-73 and PATRIOT to one million bytes will still not be adequate. PLANIT can run in as little as one and one-half million bytes of memory, an amount which is exceeded by the smallest TACFIRE configuration. Even so, TACFIRE personnel often wish there was room for more PLANIT scripts than now is the case. The use of the larger capacities in the trainer computers is a possibility, but none of the current internal computer capabilities will be adequate.

4. There exists an important policy question regarding the scheduling of training on tactical air defense systems. Some present simulation training facilities such as SIMTRACC (Simulator, Trainer, Command and Control) allow the system to continue some level of combat operation concurrently with the training. This dual operation is possible because SIMTRACC uses a separate computer facility to run the simulation. However, even if PLANIT could be run on the weapons system's own computer, it would certainly require the shutting down of the tactical operation. Not even TACFIRE can operate in the tactical mode while PLANIT is running.

5. The TACFIRE implementation of PLANIT is not being used for HOC training or SQT administration with regard to system maintenance, nor is it likely to be. This typically entails interrupting the operation of the computer for the purpose of testing hardware components. It sometimes involves having the trainee find a faulty component which was deliberately planted in the equipment. When the equipment doesn't operate, PLANIT doesn't operate and cannot dispense either training or SQTs.

While this was determined to be acceptable for TACFIRE, it may not be for USAADS. Maintenance may be proportionately more demanding for air defense systems because of the additional hardware (i.e. the integration of the radar with the computer system). Also, TACFIRE has a substantial training requirement in the learning of numerous message formats which virtually do not exist in most of the air defense systems. Thus, the need to use PLANIT for maintenance testing and training may be a relatively greater concern at USAADS.

V. CURRENT PLANIT IMPLEMENTATIONS

There are some surface similarities between existing PLANIT implementations and computer facilities which are of concern to USAADS. Specifically, TSQ-73 uses the Litton L-3050 computer and the PATRIOT Operator Tactical Trainer (OTT) uses a Digital Equipment PDP 11/70, and PLANIT has been implemented on both. (Actually, PLANIT has not been implemented on a PDP 11/70, but on other members of the PDP 11 family which are nearly compatible with it, and only minor modifications are needed to make PLANIT run on the PDP 11/70).

A. The L-3050 PLANIT Implementation

Some of the difficulties of moving the TACFIRE L-3050 implementation of PLANIT over to TSQ-73 have already been discussed. Essentially, if TSQ-73 adds as much memory as TACFIRE now uses, and if the decision is made to shut down the tactical software on TSQ-73 while PLANIT operates, then it would be quite easy to move the TACFIRE version of PLANIT to Ft. Bliss. However, despite the similarity of computer hardware, much work would remain to be done. The TACFIRE user interface is entirely different from TSQ-73. TACFIRE uses two screens, a keyboard, several dozen switches (some of which are selectively illuminated), and a printer. There is no radar sweep, no moving targets, no vector lines to be drawn, etc. Running PLANIT on TSQ-73 in a mode which resembles TACFIRE would serve no useful purpose. The user interface must be adapted, and that could be a substantial task.

Thus, there are several things which must be considered before simply attempting to move the L-3050 implementation of PLANIT to Ft. Bliss, and with current memory restrictions, it is not presently feasible anyway.

B. The PDP 11 PLANIT Implementation

The use of the PDP 11 PLANIT implementation is certainly possible, especially since the PDP 11/70 in the OTT contains sufficient memory (by supplementing core with disk). In fact, the preliminary recommendations which are presented below make use of PDP 11 PLANIT experiences, but not using the one in the OTT.

Everything which will be recommended regarding the use of PLANIT by USAADS could be implemented on the OTT's PDP 11/70. The memory space is adequate, and the interface to the PATRIOT system should facilitate that part of the task considerably. However, having determined the futility of trying to mount PLANIT within any one of the weapons systems on its own computer, and thus considering the necessity of using an adjunct computing facility, there appears to be a much more economical choice than to use the PDP 11/70 in the OTT. This thinking is based on the fact that current advances in microcomputer technology have now made hardware costs the least significant parameter among several choices.

A complete PDP 11 hardware system which will run PLANIT (in the LSI 11/23 microcomputer configuration) costs less than $25,000. It is likely that development costs for the finished package would be much more than that, especially when consideration is given to the special radar-type user interface and the necessary SQT and/or training scripts. Thus, the cost of this particular computer hardware is not likely to be a determining factor. Not only that, but a microcomputer system such as this would be portable, almost at a suitcase level.

Also, separating the PLANIT implementation from the PATRIOT OTT would permit the use of PLANIT with all six named weapons systems (and perhaps others in the future). The details of this recommendation will be presented below, including the use of videodisc and operator console mockups, but the essential point being made here is that the small cost savings realized by using the OTT computer can be more than offset by the portability and generality of a microcomputer Trainer/Tester which runs PLANIT in a stand-alone fashion.

C. The Nova Implementation

PLANIT has been installed on a Data General Nova computer (among many others). That installation has some bearing on the present study by virtue of the fact that a Nova computer is part of the SIMTRACC facility, and the configuration of options for that computer (e.g. memory, disk, etc.) is fully adequate to run PLANIT. The SIMTRACC facility provides some valuable assets, such as:

- o Adequate computer facility
- o Simulated track generator
- o Radar compatible displays
- o Existing data links to the TSQ/73 and other air defense systems
- o Shelter enclosure

However, after careful consideration, that alternative also revealed several weaknesses.

1. SIMTRACC will not benefit all six named air defense systems whereas the proposed PLANIT implementation hopefully will.

2. The radar displays are not compatible with the proposed use of videodisc players.

3. There is virtually no extra space in the SIMTRACC shelter for additional equipment, such as a videodisc player or hardcopy terminal.

4. The track simulator probably is not subject to the degree of PLANIT script control that is needed for the proposed effort.

5. The complete integration of the Nova computer with the other equipment in the SIMTRACC facility would necessitate substantial involvement with other contractors in order to add another software system. This implies additional expense.

6. The expense of relocating people to the SIMTRACC facility or relocating the SIMTRACC shelter to the contractor site could quickly offset the cost of providing a different microcomputer to do the job. As indicated in Point B above, the cost of hardware is no longer the determining factor it once was.

Thus, while the SIMTRACC computer is a possible vehicle on which to run PLANIT, other options appear to provide a better alternative.

VI. INTERCONNECTING TO EXISTING WEAPONS SYSTEMS

Given that it is not feasible to embed the PLANIT system into any of the six actual weapons systems, the next question is whether PLANIT might be implemented on an adjunct processor and interconnected to one or more of the weapons systems for SQT and/or training purposes. This preliminary report concludes that such an interconnection, although perhaps feasible, is probably not practical due to the following considerations.

A. Existing Data Links

Some of the weapons systems already have data links through which system information is communicated to other weapons systems (or to another node in a network). In fact, several standard data link formats exist (e.g. TADIL-A, TADIL-B, ATDL-1 and MBDL). At least three (PATRIOT, HAWK and TSQ-73) of the six named weapons systems have or are expected to have this kind of data link capability.

Since the SIMTRACC system already uses the data link connections to produce simulated raids for training purposes, it is reasonable to investigate the use of that kind of interconnection with a PLANIT processor as well.

The most apparent problem with using existing data link capabilities is the kind of information to be found in the data stream. Essentially, the data consists of status information regarding the battlefield, such as the targets, engagements, weapon inventories, etc. These are the kinds of information which must be communicated to make a network respond as a cohesive system. What is not present in the data stream is the record of specific operator activities.

It seems at first glance that information in such a data stream would be adequate to infer any particular operator action. After all, if an engaged enemy target suddenly disappears, that is certainly sufficient evidence that the operator took the appropriate action to make it happen. However, this is only partly true.

In the first place, the operator, being a novice, may take an inappropriate action, one which produces no visible effect on the target. A genuine training system will need to sense that condition instantly so that remedial training can be given, but the data link will not notify the training system of that event.

In the second place, data link information is passive, whereas the training system must work on active data. In other words, target status information available in the data link reflects the result of whatever operator actions were taken. This makes any training system which gets its information from the data link, operate in the passive mode. For example, if the novice shoots down a friendly airplane, that airplane disappears from the exercise, despite any contrary preferences of the training script author. The nominal benefit of that kind of training system over conventional simulators would not justify new development expense.

Instead, the training system must detect operator actions before they affect the battle, and deal with them appropriately. Some will be allowed to perform their usual function. Others will cause a corrective message to be sent to the operator, and the action will be tried again. Yet others may be intercepted, the operator notified of the error, but a corrected action will be sent to the system automatically. These are options that make up the lesson scripts in the training system. This kind of scenario requires active participation with the operator, which is not possible if the training system is limited to after-the-fact data from the data link.

In the third place, many operator actions never affect the data link. For example, if the operator chooses to magnify certain areas of the screen, move the origin around, etc., these switch actions do not change the battle scene, hence do not appear in the data link. However, these are obvious candidates for part of the SQT and training work. Operators need to be trained to perform these functions, and the training system must therefore be able to detect that kind of action, so something more than data link information is usually needed.

In order to avoid the passive nature of the data links, provision must be made in the tactical system itself which allows a training system to respond to operator switch actions. Then, the training system records the action and makes the next appropriate move. Of the six named air defense systems, only TSQ/73 has been reported to offer the needed option. INTERCON personnel report that TSQ/73 tactical software includes a training mode which provides external access to operator switch actions before any effect occurs on the simulated raid, and various alternatives can be taken. Further study of this capability might permit the interfacing of a microcomputer installation of PLANIT to the TSQ/73 through its existing data link port.

B. New Data Links

A general solution to data link inadequacy might be to physically modify the data links so that the weapons system console could be connected directly to the new trainer. This is certainly a possibility which has merit.

Many projects have interfaced military weapons system operator consoles to commercial computers for one reason or another. One could then connect the trainer to the weapons system if desired, so that the trainer could actively screen operator actions before the results of the actions were permitted to modify anything in the weapons system.

There are four serious problems with using this kind of approach for the proposed SQT Trainer/Tester system:

1. Retrofitting of existing tactical equipment would probably be out of the question. If appropriate connections were not already available on an existing plug, the process of getting that hardware changed would be lengthy, expensive and probably unwise.

2. Shifting cable connections for every training session would result in undesirable wear and tear on the equipment. It is too important that the combat equipment function properly to risk a damaged cable connection because of overuse.

3. Weapons systems consoles do not interface like ordinary computer terminals. They very often contain microprocessors whose logic interfaces with the logic in the main computer. Also, the radar sweep display is quite different from the usual cathode ray tube display on a computer. Although none of these things would prevent connecting that type of console to a commercial computer, the amount of development work necessary to make it interface properly would be enormous. It would essentially be a duplication of much of the software development effort which has already gone into the main military computer, but without the special hardware advantages.

4. Disconnecting a console from a weapons system can cripple the system so that the remaining hardware might not maintain tactical operation. If that is the case, then the use of that console for training or SQT administration would tie up an inordinate amount of expensive equipment.

C. Data Monitoring Vs. Interjacence

Existing hardware design presently allows data monitoring, but not interjacent training actions. The intent of these systems is to perform the operator action the moment it occurs. With the possible exception of TSQ/73, there is currently no known hardware or software interface among the other five air defense systems which permits the examination of the operator's action before it is implemented. While it could have been included, and even could now be added through extensive hardware and software modifications, it is not likely to be. It probably shouldn't be. If these systems are used in combat, superfluous cabling, etc., to accomodate training would add a small, unwanted increment to the probabilitly of equipment failure. Other options exist which seem to be much more acceptable.

VII. RECOMMENDATIONS FOR A USAADS TRAINER/TESTER

A. General Description

Based on this preliminary study, the computer configuration being recommended to USAADS on which to implement PLANIT for the purpose of HOC SQT administration is the Digital Equipment LSI 11/23 microcomputer supplemented with a floppy disk, a Winchester disk and a videodisc. This proposed system will not interconnect with existing weapons systems in any way, but will play the script through a mockup of a console terminal which is as nearly identical to the actual weapons system terminal as can practically be fabricated.

The software vehicle for the Trainer/Tester will be PLANIT, as described above. This report contains relatively little by way of description of the PLANIT system itself, but that information is readily available from the author or from ARI. This report only affirms that the capabilities of the PLANIT system are sufficient to encompass virtually any training or testing procedure that might be required of a typical weapons system operator.

The Trainer/Tester hardware and software system will be sufficiently portable to move among fielded sites if necessary. It would consist of the above computer configuration and a mockup console for each weapons system for which it is being used. It can be transported in a small van, or the interconnecting cables can be detached and the units can be hand carried.

The following describes each major component in greater detail.

B. The Trainer/Tester Hardware

<u>1. The Central Processing Unit.</u> A computer being suggested here is the LSI 11 microcomputer version of the Digital Equipment PDP 11/23, a recently added member of the PDP 11 family of computers. The LSI 11/23 is functionally the same as the PDP 11/23, especially in all of those features which would be important to this proposed use. In addition, it is smaller and less expensive than earlier models.

The LSI 11/23 employs the same PDP 11 architecture that is already so familiar to the Army. It also contains features which were available only on much larger models a few months ago. Some of the important features include Memory Management, Extended Arithmetic, vectored interrupts, etc. To the end user, particular features are most important which allow one to run desired software and attach chosen devices. The LSI 11/23 accepts the RSX 11M Operating System, an amazing feat for its size. RSX 11M is a sophisticated, multi-user operating system, which means that the LSI 11/23 supports that kind of use. PLANIT has already been demonstrated using that operating system environment.

The LSI 11/23 is small. A cabinet with the approximate dimensions of a large suitcase houses the entire computer, power supply, device driver cards and up to 262,000 bytes of core memory. It weighs 50-75 pounds, requires no special environmental controls and costs \$6,000-\$10,000, depending on options, amount of memory, etc. The RSX 11M Operating System runs well in 131,000 (i.e. 128K) bytes of memory. The recommendation regarding the computer is an LSI 11/23 Central Processing Unit with 131,000 bytes of core memory, the Extended Arithmetic option and the RSX 11M Operating System.

2. The Floppy Disk. Floppy disk units come in several sizes and shapes, one of which nearly exactly matches the weight and dimensions given above for the Central Processing Unit (large suitcase size and about 50-75 pounds). A floppy disk capability of some kind is becoming a norm on the smaller computers, and many of the larger ones as well. The diskette which constitutes the recording surface is about the size and shape of a 45 rpm record (eight inches in diameter but permanently contained in a paper jacket). It is flexible, unbreakable, weighs less than two ounces, and costs \$4.00 or less.

On this diskette, approximately 500,000 bytes of program or other data are randomly addressable. (Smaller versions are also available which are most often found with the home computers).

The diskette is an ideal storage medium to be used for sending programs, training scripts and SQT's to the field. The floppy disk drive usually accepts two diskettes at a time, providing a simultaneous data loading capacity of one million bytes. Data transfer rates from the diskette are as fast as from magnetic tape, but the data are typically moved much faster from diskette because of the random access. All of the data on a full diskette can usually be transferred in about a minute, and individual segments can be moved in fractions of a second.

Floppy disk units have a range of prices, but the kind envisioned in this recommendation is a dual drive, both single and dual density, uses eight-inch diskettes and shares its controller electronics with the Winchester disk. Its cost is under $5,000.

3. The Winchester Disk. This disk provides the large capacity, high speed, permanent data storage device needed to run the system and supply the training and SQT scripts to the PLANIT software. The "Winchester" name comes from a new technology for head movement on the disk surface. It permits greater recording densities (hence less size and weight per unit of data capacity) than conventional fixed disks. Very close head tolerances are made practical because the entire unit of moving parts is hermetically sealed. Head landing techniques have greatly reduced the threat of surface damage resulting from power interruptions. All in all, the Winchester disk represents a recent breakthrough in data storage technology.

Several companies are manufacturing Winchester disks. The one envisioned for this recommendation has a fixed (non-destructible) storage capacity of about 26 million bytes, enough to contain all scripts for all six weapons systems simultaneously. Its high speed helps to provide excellent response characteristics when terminal actions are taken. Data are loaded and unloaded via the floppy disk, up to one-half million bytes at a time (larger than most training or SQT scripts would ever be). The unit is similar in size, weight and dimensions to the other two; the central processing unit and the floppy disk. The cost of the Winchester disk unit can be minimized by connecting it through the floppy disk unit, making it share the controller electronics. With that arrangement, the total cost of the device is under $5,000.

4. The Videodisc. Although each of the above components represent new technology in some way, the videodisc is probably the newest. Those who are unfamiliar with the videodisc can best picture it to be like a video cassette playback unit but with either stop action or motion, and nearly instantaneous access to any one of the 54,000 (or 108,000) frames on the disc. Rather than a cassette cartridge, the videodisc plays from a round, flat surface which is about the same size as a twelve inch long play record, except that it is both flexible and unbreakable.

Even though the technology is still very new, there are already a variety of recording (and playback) techniques. The most practical for this recommendation is the optical method, where the information is taken from the disc by means of a lasar playback head which incurs virtually no wear on the disc surface even with prolonged periods on the same track to produce a still frame.

The intended use of the videodisc is discussed in more detail below, but it is essentially a convenient method for reproducing the dynamically changing image of the radar screen in such a way that every position is identifiable by a unique frame address.

Since the videodisc is still so new, an article has been included in Appendix A which provides additional descriptive information. The article is taken from a presentation at the recent Conference on Interactive Videodisc in Education and Training in Arlington, Virginia, sponsored by The Society for Applied Learning Technology, the published proceedings of which would provide yet more information.

However, the videodisc is not new to the Army. Various Army agencies have already explored uses of this device. ARI is right on the forefront of videodisc applications through its own activities and those of its contractors. That work includes a videodisc prototype which is controlled by PLANIT. The experience gained from that project will be of value in assessing the potential for using a PLANIT controlled videodisc configuration for USAADS.

The videodisc is a flexible, low cost display device. Its use in the context of this proposed facility would provide the needed capability to imitate desired portions of selected weapons systems displays in a simple, effective and easily portable way.

The discs for the videodisc player are relatively inexpensive to reproduce. The blank disc costs about $6.00. Mastering the disc (i.e. recording the initial disc) is known to be quite expensive. Much of the cost woqld result from the sheer number of pictures to be taken. The original is recorded on video tape which is then sent to a Mastering Facility where, for about $5,000, the contents are transferred to the master disc. From there, copies are stamped almost like records. It is very likely that the Army will be acquiring a disc mastering facility, which would be a significant benefit for such a project as this.

The videodisc player is again about the same size, weight and dimensions as the above three components. This would complete the fourth "suitcase." Its cost is projected to be in the $500-$1,000 range, but in this early stage of its development, it can be expected to cost in excess of $5,000.

5. Console Terminal. This will be the device through which one will communicate with the computer to initiate the training or testing sequences, to load and unload data which are sent on floppy disks between USAADS and the field, and to provide instructions to the subject regarding the training or SQT of the kind which do not normally appear on the weapons system display. It can be used for various kinds of communication, including remedial instructions, debriefing, providing a copy of score results, etc.

The console terminal can be a conventional cathode ray tube (CRT) terminal, a hardcopy keyboard/printer device, or a combination of both. A conventional CRT will cost under $1,000 and the cost of the printer will be in the $1,000-$4,000 range, depending on desired speed and quality. Both are portable, weigh less than 75 pounds, but come in a variety of sizes and shapes.

6. The Weapons System Console Mockup. This mockup consists of a television display screen and a set of interchangeable switch panels which can be placed over it. The videodisc player will cause the television display to resemble the radar sweep and target information of any selected weapons system (by loading the right disc in the player). The switch panel will complete the weapons system console mockup, fabricated to resemble the actual equipment as closely as is practical. On the various switch panels will be mounted a collection of switches, buttons and lights, to make the mockup authentic. Each switch panel will connect into a common socket on the computer.

The size and cost of these various components which comprise the mockup will depend on the degree of authenticity that is thought to be needed. However, in general, the television display can be the chassis of a home variety set, and the switch panel will be simply that--switches, lights, etc.--so it can be essentially flat panels that assemble into a console. The electronic logic which is typically found in an actual weapons system console will not be needed in the mockup since the objective is only to make the controls appear to function normally. They really do not need to do a thing other than to signal the computer that the trainee did something with them.

C. Functional Aspects of the Trainer/Tester

The recommended Trainer/Tester will operate on the above hardware configuration using the PLANIT software as a means to prepare and administer training and SQT scripts. Script authoring and modification can be done from any console terminal if the proper "key" (password) is known. Resulting scripts can be administered immediately, saved and readministered at any time, or sent via diskette to any other site. Performance data can also be sent via diskette back to USAADS if desired.

Actually, there will be several versions of the PLANIT software on each Trainer/Tester, one for every weapons systems for which it is employed. Without going into great detail, the PLANIT in each case will be the same, but the interface to the various display and input devices will be different.

This addresses a problem that is analogous to attempting to run the TACFIRE implementation of PLANIT on TSQ-73 (assuming the space somehow became adequate). Although the TACFIRE PLANIT might be made to play through TSQ-73, it would do so under the assumption that a TACFIRE console device was attached (which would of course be entirely unsatisfactory). The Trainer/Tester would solve this problem by including all needed PLANIT versions on the large Winchester disk, and using only the one which is appropriate to the particular, currently attached mockup. The appropriate version of PLANIT would then be called up by typing the name of the weapons system for which the equipment was being used.

It would be during the administration of the training or SQT that the script would direct PLANIT to make the videodisc, lights and switches functional. The videodisc will contain all radar sweep patterns that will be used for a given session. There will be a frame address for each and every pattern, and PLANIT can call for the continuous display of that frame or the display of a succession of frames to simulate the animation of the radar screen.

PLANIT scripts can also place text, lines, etc., on the screen along with the videodisc display in an electrically montaged composite picture. Such things as target identification and engagement vectors can be introduced in this manner.

One important advantage in using the above described display method is the complete control that the PLANIT script can exert over the scenario. Since every point of the simulated raid will be marked with a videotape frame address, PLANIT scripts can therefore freeze the raid, "back it up," replay arbitrary pieces, cause the raid to progress as desired despite wrong actions taken by the operator trainee, etc. This provides instructional control over the entire process as was discussed earlier in the distinction made between "training" and "exercising." For example, as a result of certain faulty responses, the script might direct PLANIT to freeze the raid display, carry on an instructional dialogue through the adjacent console terminal, then resume the raid again, hoping for better performance.

Collection of performance data is a function that PLANIT performs automatically. Whether the subject is using the system for training or is taking an SQT, PLANIT continuously monitors performance and saves information about responses. This information (called a Student Record Data Base) is ready to be used for many things, such as:

- o Dynamically adapting the script presentation according to individual needs

- o Determining which activity the subject should be given next

- o Reporting pass/fail test results

- o Indicating trouble spots in the script which leave the subjects confused

D. Special Capabilities

Two particularly useful capabilities would result from using the Trainer/Tester device as recommended:

1. Non-Interference. This proposed configuration does not attach to or use equipment from the tactical set, so its use would not interfere with tactical operation in any way whatever. This can be an important consideration, especially at field sites. In fact, the trainer system does not even need to be used in the vicinity of the tactical set if such operation is preferred.

2. Maintenance Training. Maintenance training is a difficult problem which is not even addressed by the current simulation equipment, since that, too, must have a functional tactical system to operate. However, the Trainer/Tester, being completely independent of the tactical set, could lead a trainee interactively through maintenance training and/or HOC SQT sessions. This could include performing required tests on the tactical set and reporting the results. If a test included identifying a faulty part which had been planted in the tactical set, then the SQT scenario could be developed to interpret responses in the context of the known faulty component. The importance of this point is that the SQT vehicle would continue to operate correctly even though the tactical set was taken out of

operation for maintenance.

E. Expected Problems

Panaceas are very hard to find, and this recommended Trainer/Tester is not expected to be one. Problems have a way of showing up as any project progresses. These are a few that can be anticipated.

1. Authenticity. The soldier should be able to move from the Trainer/Tester to the actual equipment and immediately use that which was learned. In the case of SQTs, performance on the Trainer/Tester must be similar enough to accurately measure how much the soldier knows about operating the real thing. This will probably depend on the degree to which the mockup and the presentation on it is authentic.

Costs will probably prevent the mocking up of the entire weapons system shelter environment. Thus, if restricted movement, surrounding noise, etc., play a significant role in performance, that element might be missing in the Trainer/Tester.

2. Hardening. There may be a short-term problem in that this new equipment is probably not yet available in ruggedized form. Whether that would be a major problem for the Winchester disk would need to be determined. The Winchester disk is known to be reasonably durable if certain precautions are taken when it is transported and so long as it is not jarred during operation.

3. Resolution. This pertains primarily to the television display which replaces the radar screen, but can have application to other equipment as well.

The television screen for the videodisc player is a standard, raster scanned video. This means that the displayed image is drawn by means of closely spaced horizontal lines, varying the intensity as the beam moves along the horizontal path. It will use the 525-line commercial format or the 600-line closed circuit TV format. In either case there are very fine gaps between the lines which are not illuminated. This results in a degradation in picture quality compared to the typical radar-type display where the beam sweep exactly follows the path that is to be painted (i.e. using a vector generating beam). The latter produces sharper, better defined lines and characters than does the raster scan method.

This difference in image definition (or resolution) might be noticeable especially in the case of the small print used on the screen for target identification. It may be that the poorer resolution on a raster scanned screen would render such small type illegible, requiring the use of larger print (reducing authenticity and using more of the available screen surface).

Another resolution problem results from the weapons system's capability to magnify the display in several steps, and to move the center point as needed. If this important capability was implemented on the Trainer/Tester by including each of the possible alternatives in videodisc frames, even the vast number of available frames on that device would soon be exhausted. It may be necessary to introduce that capability into the deflection circuits of the television set in order to produce the desired effect.

These are the kind of resolution problems that will need to be studied. Complete authenticity and equal resolution can only be assured on identical equipment, and even though the suggested alternatives have certain training advantages, basic design differences of this kind could lead to some degree of user perceived differences.

VIII. CONCLUSIONS AND NEXT STEPS

This report contains preliminary recommendations. Several questions have been left unanswered, the resolution of which will require much more than the few days allocated to this effort. Questions regarding the applicability and authenticity of the videodisc as a substitute for a radar display will probably require some trial experiences with that device before making a final judgment as to whether the recommended configuration is viable.

The adjunct computer equipment is also a matter for discussion. The PATRIOT trainer uses a Varian processor which could work well here if conditions warranted. The use of the PDP 11/70 in the OTT or the Nova computer in the SIMTRACC shelter are possibilities, too.

There also are several options available if a microcomputer is used. Most of the components which were discussed above (central processing unit, floppy disk unit, and Winchester disk) are being packaged into a single cabinet the combined weight of which is under 100 pounds. Memory capacities are smaller, but the tradeoff may be considered worthwhile to ease the transport problems. (The Winchester disk in that unit has a 10 million byte capacity, and the floppy disk has only one drive).

A further investigation into a training system such as the one recommended seems to have merit. If such a device as this became a reality, the savings in instructor and travel costs could pay out the developmental costs in a short time. HOC SQT administration would become standardized. Good instructors could multiply themselves, spreading their talents via lesson scripts on diskettes to virtually every air defense site in the world. There are many badly needed possibilities here that today's technology can help to supply.

A reasonable inquiry into some of these ideas would be to commission a demonstration of a Trainer/Tester prototype, choosing carefully among several options with the intent to defer the larger development expense to a point after which an informed assessment can be made about the quality of expected results. This can be done in the following ways:

1. Rent time on an existing computer system configuration that uses the components thought to be desirable for the finished system. This would reduce initial equipment purchases.

2. Piggyback the videodisc work with an existing ARI effort, or use a video cassette player as an inferior substitute for the initial display needs. This will avoid the high mastering costs and the current premium prices being paid for the initial production lot of videodisc players.

3. Choose only one weapons system for the initial demonstration.

4. Choose a short (20 minute) segment of representative training and a corresponding HOC SQT over the same material. This amount of time should be enough to assess the applicability of the method without incurring unduely high authoring costs. Also, the radar sweep display materials (which will probably be the most costly) that are prepared for the training segment can probably be reused for the SQT segment.

5. Accept a mockup which is built from commercially available parts, knowing that it can be rebuilt in the future to any desired degree of authenticity if other conditions warrant it.

The above project could probably be completed in eight to ten months for less than $75,000. For that amount the Army would view a short demonstration on the basis of which a further step could be decided. Purchasing Trainer/Tester equipment which could be delivered to the Army for further testing might add another $25,000-$30,000, but that might be a better alternative, giving the Army added opportunity to investigate its potential. If the twenty minute segment was too short the project could be expanded as necessary. The results could be used to determine whether and under what conditions to proceed.

IX. REFERENCES

Frye, C. H., TRANSL - The PLANIT Translator Program: Installation and Application, U. S. Army Research Institute, June 6, 1975.

Hoyt, W. G., Butler, A. K. and Bennik, F. D., Application of Tactical Data Systems For Training: Volume II - AI/DEVTOS Automation Studies, Research Memorandum 74-8, U. S. Army Research Institute, July, 1974.

APPENDIX A

TRANSPORTABLE SOFTWARE

TRANSPORTABLE SOFTWARE

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ABSTRACT

This paper discusses transportable software particularly as it might apply to emerging videodisc technology. The videodisc is a powerful new tool for information storage and retrieval with a very large frame capacity and random access capability that is nevertheless within an affordable price range. Cost and ease of reproduction combines to suggest new alternatives for training applications, but the large capacity of frames will demand a management capability, probably using a computer. Microcomputer technology has already been coupled with the videodisc to control the display. Thus, it appears certain that computer programming will need to be involved.

With computer programming comes the need for transportable coding, lest videodisc platters come into being which will only play with a certain brand of computer. That would be an unfortunate restriction. Since videodisc technology is still so new, there is time to develop transportable coding standards to avoid this problem.

INTRODUCTION

The use of audio-visual materials in many forms is a way of life today. Repositories of such materials are innumerable and the amounts of money which have been spent to enhance their display would stagger the imagination.

As this menu continues to grow, the problem of selecting the intended materials in a timely manner and desired order becomes acute. Also, with several choices available for displaying them (still, motion, lapsed time, full color, montage, etc.), the technologists have been busy trying to provide the kinds of innovations which give this viewing flexibility.

A great many random selection methods have been tried with varying degrees of success, including devices which randomly access slides, motion picture segments, microfilm and microfiche images, etc., in an attempt to provide external program control over the timing and order in which the visuals are selected for viewing. These typically run the gamut from a hand-operated image selector to a computer-driven cathode ray tube with a built-in window through which a projected image is overlaid on the screen.

Of course, video tape and video cassette recording (VCR) devices are among the more recent innovations that have been examined for that purpose. Now, with the introduction of the videodisc, it seems that we are nearer the goal than ever before.

INNOVATION

In the field of communications, the videodisc is probably considered to be the glamour innovation of the decade. Its low cost, high storage capacity, and variety of viewing options suggests widespread use.

It would be useful to review some of its more prominent advantages in the context of prior capabilities.

Comparable Advantages

Some videodisc advantages are comparable to existing media while others, for the moment at least, are unique. In considering some comparable advantages, it will also help to review some characteristics of the videodisc.

Storage Capacity. The large storage capacity of the videodisc is certainly a great advantage. It has been said that one disc could hold the entire Encyclopedia Britannica set and still leave ninety percent of the disc empty.

In fact, a typical disc will hold either 54,000 or 108,000 full-screen still frames, depending whether the disc is meant to play 30 minutes or 60 minutes (and other capacities are sure to be announced if they haven't already). These figures are derived from the industry standard for presenting 30 frames per second to achieve a perception of motion. Although a 54,000 frame disc has certain random access advantages at the moment (as discussed below), the one-hour (108,000-frame) disc is likely to have more popular appeal.

The price of storage has long been a major concern, especially to computer users. It was not long ago that storage cost was quoted as the price-per-bit. In the case of a videodisc, that price would be such a small fraction of a penny that it would be practically useless.

Computer storage is ordinarily rated in "bytes" (where one byte is equivalent to the storage of any one typed character). In order to make the comparison of videodisc storage figures more meaningful, it might be useful to calculate the number of bytes on a 108,000-frame disc. The industry standard for a full screen of a cathode ray tube terminal seems to have settled at twenty-four 80-character lines, or 1920 characters (bytes). If such a full screen constitutes a frame, then a one-hour videodisc would store the equivalent of 207,360,000 bytes, or about 200 MB (megabytes, i.e. million bytes).

It can easily be argued that 1920 bytes per full screen frame in not an accurate estimate since a byte of computer data carries only eight "bits" of information, while the corresponding character space in the frame carries intensity, color and contrast information which would exceed eight bits by a wide margin. On the other hand, a televised picture of a twenty-four line, 1920-character page typically has such poor resolution that it is nearly unreadable, and only when computer-like character generation procedures are used does a page full of characters of that magnitude become usable. Thus, a 200 MB videodisc capacity seems like it might be a valid figure for comparison.

A 200 MB storage capacity is certainly a respectable amount of space, but not enough to be unique. To put this amount into perspective, a 2400-foot computer tape holds 40-45 MB, and several computer disks exceed the 200 MB figure, with 300 MB being fairly common. Of course, the cost is substantially different, but that will be discussed a little later. The point here is that we are already familar with storage capacities in the computer field which equal or exceed the videodisc, and apart from the computer field, the six-hour VCR cassettes would contain more than a billion bytes (1,000 MB) by the same measure.

Random Access. Most videodiscs permit rapid access to any section of the recorded images. Many will randomly access any one of the 54,000 frames. Because the disc is so compact (about the size of a 12 inch long play record), random access is quite fast. Thus, optically recorded discs which are recorded in 54,000 track format, one frame per track, usually permit access to any one of the 54,000 frames within a second or less. With the application of Winchester and other new technology, one may assume that single frame random access will soon be available on most if not all videodisc players, regardless of the recording method or number of frames.

Random access to individual frames provides some exciting advantages. Not only can the disc be played in 30 frames per second motion sequence, but also in stills, slow forward, slow reverse, lapsed time, compressed time, or whatever. All it takes is a method to implement a series of frame accesses, and a microcomputer has been shown to do that quite satisfactorily. However, not all of these features are new with the videodisc.

Computer disks have always required full random access to any data on the disk and have been used to record and replay video information as well. VCR's also characteristically permit a degree of frame selection.

Although the one second access time cannot be assured due to the length of the tape, features have been demonstrated for locating any desired frame (or at least as close as the adjacent frame). One has only to view a televised football game to appreciate the variety of frame display options which have predated the videodisc. Again, the cost of such equipment may not be comparable, but that is yet to be discussed.

It should also be noted that recent advances may significantly improve random access on video cassettes. The Longitudinal Video Recorders (LVR), recording in 220 seventeen-second parallel longitudinal tracks instead of a continuous helical scan, offers to provide nearly instantaneous access of any one of the tracks.

Thus, while random access is certainly an advantage for videodisc, it is not a unique one. By the same token, many of the present disadvantages of videodisc are not particularly important because of the rapidly developing state of that technology. For example, several institutions are at work on models which will do home recordings, a feature which the VCR manufacturers claim as their significant advantage.

Unique Advantages

There are at least two advantages which seem to fit this category that are of particular importance to this presentation, one relating to cost and the other to data transmission.

Cost. Videodisc players are expected to sell in the ballpark of $500 once they are in full production, and discs should cost about $6 plus royalties, a price which should put them well within reach of the home market.

It can be argued that this price is still not inexpensive, especially not enough so that one can be allowed to tie up a player for solo viewing. However, that depends on its usefulness. One can think of many costlier items which are often (or usually) used solo, such as an automobile, motorcycle, piano, organ, hi-fi, home computer, computer terminal, etc. Thus, if the videodisc is deemed to be useful enough, the price will be acceptable.

Another cost consideration will be that of mastering the disc, a price which few can afford. While it is likely that home recording capabilities will someday be offered for videodiscs, this presentation assumes that recording costs will be spread over the mass sales of discs, adding a few dollars to the cost of each disc. This will be discussed more a little later.

It will probably also be noted that the VCR will continue to be competitive with the videodisc, and the LVR might even undersell it. However, cost must be compared relative to performance, and the videodisc will probably deliver a lot more for the money.

Thus, the unique cost advantage of videodisc owes itself to the very flexible display options (stop-, slow-, normal-, and fast-motion) including montage composites with other generated displays, all with little or no wear on the recording surface. As if this isn't enough of a cost advantage, the next point to be discussed also has cost reduction implications.

Data Transmission. The rapid transmission of data is a matter of growing importance in our society. Data transfer rates are often critical variables in computer systems. Moving data via electronics has enabled feats which were impossible a few years ago.

Data transmission in a computer is typically measured in the number of bytes (keyboard characters) per second. A reasonably fast computer disk can be expected to transfer approximately 100,000 bytes per second. It would tax a large printing press to copy that many characters so quickly.

Now consider the process for copying a videodisc. The disc is stamped from a master, much like a conventional record. Unlike all other copy operations in which some or all of the data are transferred serially, the stamping of a disc constitutes a completely parallel data transfer.

In the infancy of the technology it takes only a few seconds to stamp the videodisc. In that few seconds, 207,000,000 bytes of information have been copied. It is probably reasonable to suppose that mass production will soon reduce that time to a second or less. If the reproduction rate could be increased to five discs per second, that would constitute a data transmission rate of a billion bytes per second. The information exchange rate becomes several thousand times faster than printing books, with machinery which probably costs very little more. This clearly puts the videodisc in a class by itself. No other technology moves data so quickly, and that translates into lower costs.

IMPLICATIONS

There are some important implications which result from the new videodisc capabilities.

Menu Selection

A 108,000-frame videodisc will play for one hour at 30 frames per second. It could also be viewed in single frame mode.

In order to grasp something of the immensity of the frame storage capacity, suppose each of the 108,000 frames was viewed in a learning setting for 30 seconds. That would amount to 900 hours of viewing time, or equivalent to two years of student contact hours in college. If that disc was recorded on both sides, a student could theoretically carry a four year college curriculum in a record jacket.

That this might happen is not even being suggested. What is being implied, however, is that a single disc has far greater capacity than would typically be used for any particular course of study (unless the disk was being used only for motion picture presentation). This will probably lead to the inclusion of far more learning materials on a single disc than a course author (teacher, lecturer, computer-assisted instruction author, etc.) would use. Thus, accompanying the disc would be a menu from which the author would select only those frames and/or segments which happen to fit the course objectives.

The suggestion that discs which are distributed for learning purposes will typically contain far more materials that one would normally use is further supported by the high mastering costs versus the very inexpensive reproduction costs. It would be more cost efficient to include materials on a single disc which appeal to the widest possible audience in order to distribute mastering costs across a larger sales volume. This strategy is already at work with cable TV which also has very high origination costs versus nominal distribution costs. The menu comes in the form of TV channels, and the cost considerations make it most practical to supply every customer TV with every program selection, then introduce a local menu control (in the form of Showtime boxes, etc.) to market the media.

Thus, the learning-oriented disc will comprise a library of materials for the subject. It will then be the task of the author, supported by some sort of disc management system, to organize a subset of the materials to suit the intended purpose.

Disc Management System

The amount of material which can be catalogued on a single videodisc will require a management system to make it accessible. Consistent with the technology in the videodisc, that management system will probably be a microcomputer.

Given a microcomputer management system, it would then be quite practical to sell discs with "keys" which would unlock purchased video sequences. The keys could easily be in the form of computer chips which would automatically select the desired sequences. We are already beginning to see this kind of marketing strategy in hand-held calculators and electronic games. It is fairly safe to predict that videodiscs might be marketed together with optional plug-in chips, each of which would unscramble a particular video sequence. The chip, costing about ten cents, might sell at enough markup to recover mastering costs. Given the management key to these materials in a chip which plugs into the microcomputer, the author is then able to orchestrate the sequence in which the materials will be displayed.

If such a strategy was to be implemented, it could stimulate a vast amount of free-lance work on the part of artists and scientists who benefit from their work by receiving dividends from the sale of chips. This would of course not interfere with the production and sale of discs which had a unified theme (movie, etc.), for which a management chip would be unnecessary.

Authoring Systems

Unless the videodisc is to be used in its most simple motion picture mode, it is clear that designers of courses will have to have authoring help. Continuing with the assumption that a microcomputer will be involved, the required help can readily be provided by means of an authoring language on that computer.

The implication here is that videodisc-mediated learning and computer-assisted instruction (CAI) will probably go hand-in-hand.

More than two decades of effort have gone into perfecting computer-aided authoring systems. Several authoring languages have been devised, some of which are currently available. By coupling a CAI system to a videodisc, the learner can interact with the video presentation. WICAT is doing this with the PLANIT CAI system. With this facility, the authoring is done interactively, such that directives for presenting videodisc frames or movie sequences are entered into a lesson script along with the question and answer processing directives. This makes a very effective learning tool.

Impact of Videodisc on CAI Systems

Computer-assisted instruction systems provide facilities for presenting stimuli to the learner and for analyzing and managing responses. The stimuli presentation portion is the more visible, and has captured the larger share of attention. For example, many millions of dollars have been spent to make the PLATO system produce excellent graphic displays.

However, conventional videodisc displays will equal the best PLATO displays and add a color dimension as well. Thus, the introduction of videodisc into CAI systems will substantially equalize the stimuli presentation capabilities of all systems, and the focus of attention will probably turn to response analysis and data management, an impact which should produce beneficial results both for authors and learners.

INSTALLATION

Videodisc players which are purchased at the local retail outlet and connected to the home television set will have few installation concerns. The bill of fare seems mainly to be television movies. At most, there may be opportunity to scan to a preselected frame and control the mode of presentation from there.

On the other hand, videodiscs which are used in other settings such as educational, commercial and military, are more likely to contain the kinds of programming which will require the sophistication of a computer to manage the display. It is also likely that such settings will include an interactive component for such applications as training, testing, and/or natural language selection formats for desired viewing.

If computers are to be involved, then so will computer programming, and it is at this point where proper planning can avoid a great deal of future expense.

Standards

Recording format standards are certain to be a major topic in regard to the several videodisc playback methods. Such standards have been developed for video tape and video cassette, so one would expect that they would be for videodisc as well.

The standards that are all too often ignored are those pertaining to the computer programs. If computer programming is to be a part of a videodisc system, and it probably will be, then the standards must be as stringent for the computer software as for the recording format if they are to be meaningful.

Standards committees that have dealt with computer programming languages in the past have too often acceded to private interests and accepted substantial differences in language implementations to nevertheless fulfill their qualifications. Only an expert can explain why two common language systems which have been developed according to the same set of standards, run programs which are mutually incompatible.

The state of videodisc technology is at a point where this could be avoided.

Transportable Software

There exists an authoring language and software system called PLANIT. It is a multi-terminal operating system for authoring, testing, computing, taking lessons and/or tests, and many other dialogue applications. PLANIT provides as much authoring facility as one is apt to find in such a language, and it is easy to learn and use.

PLANIT can easily integrate videodisc frame (or movie segment) selection with interactive training material. However, more significant than being an excellent CAI system, PLANIT is portable. It can run on virtually any computer that is large and fast enough for typical CAI applications. It has run on most of them, from a micro to a mainframe. PLANIT has been embedded in other computer systems, including weapons systems for the U. S. Army. The Army Research Institute has performed extensive validation studies in regard to PLANIT's portability, with complete success.

It is not unusual to find a given language running on a variety of computers. Languages like BASIC and FORTRAN are running on most of them. The difference is that every PLANIT installation has originated from the same physical source code, whereas BASIC or FORTRAN is rewritten for each new kind of computer that uses it. Also, because of the rewriting process, it is common knowledge that a BASIC or FORTRAN program that is written for one computer will rarely run without major modifications on another. PLANIT programs (lesson scripts) are always 100 percent compatible on any

PLANIT implementation because the same source files produced all systems.

This could be taken as a pitch for using PLANIT. One can do worse. However, the intent is to demonstrate that transportable programs can be written if we want to badly enough. If serious use of the videodisc is likely to involve computer programs of some sort to manage the vast frame capacity, then it would certainly be to everyone's benefit to make those programs transportable. It would be most unfortunate to sell a disc which only runs with Brand X kind of computer.

In the first decade of commercial computing, transportable programming was a matter of great interest, was discussed in professional meetings and was described in several publications. Then silence prevailed. Good software was readily available, even though it didn't happen to be transportable and there was little motive to insist that it be so. Now we are like the cities that have sold their trollies, pulled up the tracks and torn down the wires. Software development and conversion costs are becoming unbearable because we opted for the machine dependent approach. In fact, we have nearly convinced ourselves that it must be so, and view with skepticism any claim of transportability. Had we maintained the transportability momentum from that first decade, the technology would have been far advanced today. However, transportable programs are possible, have been demonstrated and should be of particular interest for developers of computer-controlled videodisc.

CONCLUSION

This conference is specifically directed at videodisc technology, as have been several others recently. It isn't the videodisc device that is so important. Rather, it is the need for inexpensive retrieval methkds for quality information, to be displayed in its most useful form. If bubble memories eventually outperform the videodisc, so much the better. It is really the information that matters, how to find it, reproduce it, put it into the proper sequence for optimum learning, time its presentation for greatest impact, check our success by evaluating learner responses, and do it all within the next year's budget. Maybe someday we can.

ABOUT THE AUTHOR

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